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PHOTOGRAPHIC OBSERVATIONS OF THE RING
NEBULÆ IN *LYRA* AND *CYGNUS*.

BY JAMES E. KEELER.

Of the four annular nebulae known to the HERSCHELs, only two are visible — or easily visible — in northern latitudes. One of these is the Ring nebula in *Lyra*, familiar to all observers with small telescopes. The other, in *Cygnus*, is small and faint, and hence has been very little studied. Many of the planetary nebulae are bounded by bright rings, or contain bright rings within an outer and fainter limit; but for various reasons these nebulae are usually placed in a separate class.

In connection with a series of researches on the nebulae, now in progress with the Crossley reflector, the two ring nebulae above mentioned were photographed a number of times during the past summer. In what follows I give briefly the substance of a paper which was read before the conference of astronomers at the Yerkes Observatory, in September.

The Ring Nebula in Lyra.—Several very good drawings have been made of this nebula, the best of which, in my opinion, is one made by Professor HOLDEN with the 26-inch refractor of the U. S. Naval Observatory. The original is in the library at Mt. Hamilton. All the drawings agree in showing an elliptical ring, fainter near each end of the major axis, and filled with faint nebulosity. This nebula has also been successfully photographed by many observers. In some respects, the photographs which have been obtained are superior to the eye observations. Thus, a small star exactly in the center of the ellipse is easily photographed with even a small instrument. Visually, however, it is very faint. It is not shown in the drawings of Lord ROSSE and LASSELL, and it escaped TROUVELOT with the Harvard 18-inch and HOLDEN with the Washington 26-inch refractor. There is, I believe, much reason to suppose that this star is variable, though it has remained practically constant in brightness for a good many years. Its magnitude is 15.4, according to an estimate by Professor BURNHAM, in 1891.

But the Ring nebula is not such an object as the photographic telescope, in its usual forms, is capable of dealing with most successfully. In reflecting telescopes the focal length is generally

short, and hence the image of the nebula is very small; in photographic refractors the actinic power of the nebula's light is greatly weakened by the absorption of the glass lenses. The most suitable instrument for photographing the Ring nebula would be a large reflector of unusually great focal length.

The Crossley reflector has a focal length of 17 feet 6 inches, and the diameter of the nebula on the photographic plate is about 2^{mm}, or 0.08 inch. If the focal length were, say four times greater, the image would still be bright enough to photograph with a reasonably short exposure, and the pictures of the nebula would doubtless far surpass any ever made.

A great deal of detail is however visible in an image 2^{mm} in diameter, while the brightness of the nebula makes the exposure times very short. The following list of negatives made with the Crossley telescope under very fine conditions shows the photographic efficiency of the instrument very clearly:—

1899.

- July 13. Exposure 2 hours. All parts of the nebula greatly over-exposed.
- July 12. Exposure 1 hour. Over-exposed.
- July 14. Exposure 30 minutes. Good photograph; treated for over-exposure.
- July 14. Exposure 10 minutes. Best general picture of the nebula.
- July 14. Exposure 2 minutes. Distinct image.
- July 14. Exposure 1 minute. Faint image.
- July 14. Exposure 30 seconds. Barely visible image.

With refracting telescopes exposures of nine, ten, and even twenty-four hours have been given to the Ring nebula. Such excessive exposures would be useless with the Crossley telescope, as they would merely produce a great black blotch on the plate.

From the best of the negatives in the above list, positives were made on glass with an enlargement of about eleven diameters. These positives, requiring no magnifier for their examination, were more convenient for many purposes than the original negatives.

The most interesting discovery resulting from an examination of the photographs is that the Ring nebula is made up of a number of narrower rings interlacing somewhat irregularly, the spaces between the component rings being filled with fainter nebulosity. One of these rings forms the preceding end of the main ring. Sweeping around to the north end of the minor axis, it becomes

very bright, perhaps by superposition on the broader main ring of the nebula at this place. It crosses this ring obliquely, forming the brightest part of the whole nebula, and then forms the inner boundary of the main ellipse toward its following end. Another of the narrow rings forms the inner boundary of the ellipse on the north side; it crosses the main ring obliquely, and on the south projects beyond the elliptical outline of the nebula, converting it into an oval whose more pointed end is toward the east.

There are other, but irregular and much fainter, projections of nebulosity beyond the general outline of the nebula, at a number of places on the ring, particularly at the two ends. The position-angles and amount of projection have been measured for all these nebulous masses, but it is unnecessary to give the results here.

The nebulosity within the ring, which appears in ordinary telescopes like a faint uniform veil, has a very interesting structure on the photographs. Lord RosSE's drawing in the *Philosophical Transactions* for 1844 shows the interior space of the nebula crossed by a series of dark and bright bands in the direction of the major axis, and this drawing has, I think, generally been regarded as fanciful. Nevertheless, the structure it represents is confirmed by the Crossley photographs — and confirmed, so far as I am aware, for the first time. There are, however, only three dark and two bright bands within the ellipse. One of the dark bands is centrally placed. The direction of the bands is not exactly that of the major axis of the main ellipse, but in a position-angle about 5° greater.

The details described above are not visible, or can at most be only suspected, with the 36-inch refractor, notwithstanding the brightness, large size, and fine definition of the nebula as seen with this instrument. The advantage of the photograph in this case lies in its exaggeration of differences of brightness which are too small to affect the eye in visual observation.

Besides the central nucleus, the photographs show only one star within the darker inner space. It is just visible at times with the 36-inch refractor, and its magnitude cannot be far from 16. There is also a star discovered by Dr. HOLDEN at the preceding extremity of the major axis. Other stars which have been seen in the ring by various observers seem to be bright patches caused by the interlacing of the component rings.

In 1893, Professor BARNARD* discovered a small nebula, near

* *Astronomische Nachrichten*, No. 3200.

the Ring nebula in *Lyra*, with the 36 inch refractor. The Crossley photographs show that it is a left-handed, two-branched spiral, with an extreme diameter of about 30".

The Ring Nebula in Cygnus (*G. C. 4565*).—This is a nearly circular nebula, only about half the size of the one in *Lyra*, and very much fainter. There is a drawing by Sir JOHN HERSCHEL in the *Philosophical Transactions* (1833),* in which the nebula is represented as a faint ring without detail, and one by Lord ROSSE,† in which the faint nebulosity within the ring is also shown. I do not know of any other published drawings or of any photographs whatever.

Two photographs of this nebula were made with the Crossley reflector in August of the present year, and from one of them, to which an exposure of two hours was given, enlargements were made in the manner already described.

As shown on the photographs, the nebula is a nearly circular ring, measuring 42".5 by 40".5. The outer boundary is fairly sharp. On the inside of the ring the brightness fades somewhat gradually toward the center, which is marked by a nucleus, or star, of about the sixteenth magnitude. At several places, narrow streaks of nebulosity project from the inner edge of the ring, part way to the center, like imperfect spokes. One bright star (14.5 mag.) is shown on the ring. It was observed by Lord ROSSE. There is no evidence that this star is physically connected with the nebula, and its position on the ring is probably an accidental effect of projection. The nebula is surrounded by small stars, the distances and directions of which from the central nucleus have been measured on the photographs, in order that any proper motion of the nebula may be detected by repeating these observations at some time in the future.

THE RISE AND PROGRESS OF ASTRONOMY IN CENTRAL EUROPE.—III.

BY SIDNEY D. TOWNLEY.

Although without a rival as a practical astronomer, still TYCHO BRAHE was not without contemporaries. The science of astronomy was being advanced by a few persons in Germany, chief

* Plate XIII, fig. 48. † Observations of Nebulæ and Clusters of Stars, Plate V.